Tropical precipitation breakdown by ISCCP weather state

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In order to understand the water budget of the planet it is important to measure the rainfall distribution. We can now achieve relatively good rainfall estimates from satellites over almost the entire planet. Measuring only rainfall amounts is however not enough to understand the underlying physical processes determining where, when, and how much rainfall occurs. We must also observe and measure other atmospheric characteristics related to rainfall, such as cloud properties. In this paper we propose a method to help us better understand what cloud regimes (as defined by distinct "weather states") the precipitation of the extended tropical region originates from. The tropics are of special interest because they cover about half the area of the planet and produce the strongest rainfall intensities. We can "map" the tropical precipitation by weather state by combining different satellite measurements targeted to rainfall and joint cloud optical thickness/cloud top height distributions. An important finding is that in the tropics about half of the total rainfall comes from one particular type of cloud mixture, associated with deep storm systems, WS1 (Fig. 2). Surprisingly, our combined datasets indicate that even these clouds are often (about half the time) not precipitating (Fig. 3); when they do, they tend to precipitate stronger over ocean than over land. Our analysis indicates that this is because oceanic cloud regimes associated with WS1 are larger and longer-lasting. The results may be used to investigate whether climate models partition precipitation in accordance with observations and to therefore indirectly assess whether predictions of future precipitation in a changed climate can be trusted.

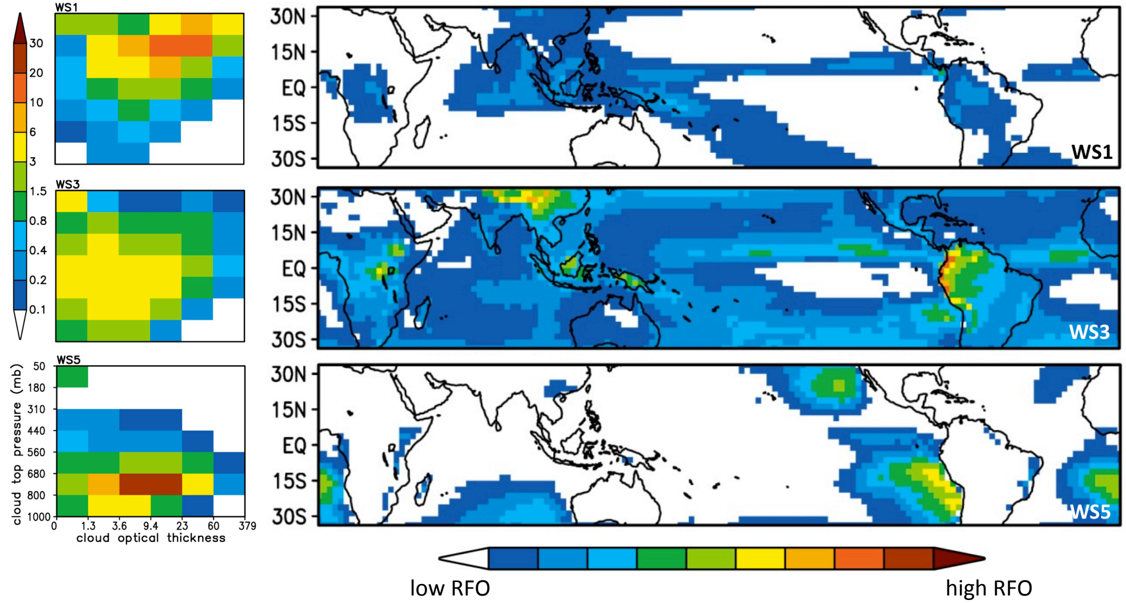

Figure 1: Maps of the relative frequency of occurrence (RFO) for three (of eight) tropical weather states (WS) defined by the joint histograms of cloud top pressure and optical thickness

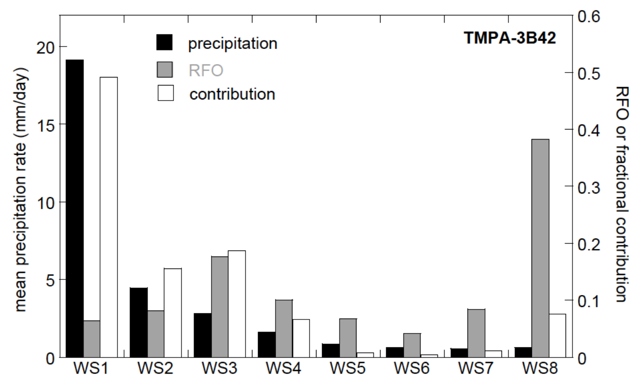

Figure 2: Domain-average values of the mean precipitation rates and fractional contributions to the total tropical precipitation. Also included is the domain-average RFO of each weather state.

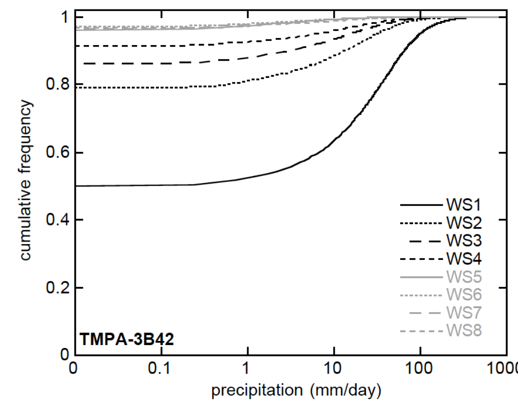

Figure 3: Cumulative histograms of precipitation rate for each of the eight tropical weather states.

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References:

D. Lee, L. Oreopoulos, G. J. Huffman, L., W. B. Rossow, and I.-S. Kang, 2012: The precipitation characteristics of ISCCP tropical weather states. *J. Climate*, in press. Preview available at http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-11-00718.1

Data Sources: International Satellite Cloud Climatology Project (ISCCP) weather states, TRMM-adjusted merged-infrared (IR) precipitation (TMPA-3B42) and Global Precipitation Climatology Project (GPCP-1DD) precipitation.

Technical Description of Figures:

Figure 1: Maps of the relative frequency of occurrence (RFO) for three tropical weather states defined by the joint histograms of cloud top pressure and optical thickness to the left (the vertical colorbar indicates % occurrence within each bin). The RFOs come from 10 years (1998-2007) of ISCCP data. The three (out of eight in this region) cloud regimes chosen represent cloud mixtures dominated by deep convection (WS1), unorganized convection with large amounts of cumulus congestus (WS3) and marine stratocumulus (WS5).

Figure 2: Domain-average values of the mean precipitation rates and fractional contributions corresponding to each of the eight tropical ISCCP weather states . Also included is the domain-average RFO of each weather state. One can see that despite an RFO of only ~6%, WS1 contributes about half of the total precipitation in the ±35° latitude zone. This is because the mean precipitation rate of ~19 mm/day for this state is more than four times larger than that of the next strongest precipitating weather state (WS2).

Figure 3: Cumulative histograms of precipitation rate for each of the eight tropical weather states. The strongest precipitating state, WS1, about half the time WS1 is not precipitating according to TMPA-3B42. This large fraction of non-precipitating deep cloud systems may however be an overestimation given the inherent weakness of the algorithm to detect light precipitation and our inability to achieve exact spatiotemporal matching with the data sets at hand. Still, WS1 produces precipitation rates greater than 70 mm/day about 10% of the time.

Scientific significance: Since clouds are the most prominent regulators of radiation and precipitation, the connections between precipitation, radiation, and the state of the atmosphere as a function of cloud regime using a weather state framework should be further explored. To some extent work along these lines has already been performed, but the unifying effort that will fully integrate the physical relationships between atmospheric dynamical and thermodynamical states and the budgets of radiation and precipitation into a coherent picture has not yet materialized. Once such an effort is completed, a better foundation on how to analyze cloud regimes and associated meteorology in conjunction with energy and water budgets will be available for climate models to capitalize on. This can potentially lead to significant leaps in the quality of model hydrology and energetics.

Relevance for future science and relationship to Decadal Survey: Our understanding of how different cloud regimes contribute to the water budget of the planet needs to be improved. One way of achieving this is to combine cloud classifications from passive and/or active sensors with simultaneous space-based precipitation estimates. Such studies can be conducted with NPP/JPSS and GPM cloud and precipitation retrievals.